SPECIES Scholarships

University of Coimbra

Curriculum Vitae

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Keywords: Artificial Intelligence , Evolutionary Computation, Machine Learning, NeuroEvolution

Nuno Lourenço is an Assistant Professor at the Department of Informatics Engineering of the University of Coimbra, where he obtained his PhD in Information Science and Technology in 2016.
He is the coordinator of the Evolutionary and Complex Systems (ECOS) group, and has been a member of the Centre for Informatics and Systems of University of Coimbra (CISUC) since 2009.
Formerly, he was appointed as a Senior Research Officer at the University of Essex in the United Kingdom. His main research interests are in the areas Bio-Inspired Algorithms, Optimisation and Machine Learning. He is the creator of Structured Grammatical Evolution, a genotypic representation for Grammatical Evolution, and participated in the proposal of a novel approach to automatically design Artificial Neural Networks (ANNs) using Evolutionary Computation called DENSER. He served as publication chair for two of the most important conferences of the Evolutionary Computation field, namely the PPSN XV and EuroGP 2019. He will be chair of EuroGP 2020. He is a member of the Programme Committee of some of GECCO, PPSN, EuroGP; member of the Steering Committee of EuroGP; and executive board member of SPECIES. He has authored or co-authored several articles in journals and top conferences from the Evolutionary Computation and Artificial Intelligence areas and he has been involved as a researcher in many national and international projects.

Penousal Machado

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Keywords: Evolutionary Computation, Computational Creativity, Artificial Intelligence, Information Visualization

Penousal Machado is Associate Professor at the Department of Informatics of the University of Coimbra in Portugal. He is a deputy director of the Centre for Informatics and Systems of the University of Coimbra (CISUC), the coordinator of the Cognitive and Media Systems group and the scientific director of the Computational Design and Visualization Lab. of CISUC. His research interests include Evolutionary Computation, Computational Creativity, Artificial Intelligence and Information Visualization. He is the author of more than 200 refereed journal and conference papers in these areas, and his peer-reviewed publications have been nominated and awarded multiple times as best paper. Until May 2019 his publications gathered over 2262 citations, an h-index of 24, and an i10-index of 51. He was the advisor of 7 PhD thesis and 39 MSc thesis, and is currently advising 9 PhD and 3 MSc thesis.

He is also the chair of several scientific events, including, amongst the most recent, ICCC 2020, PPSN XV, and EvoStar 2016; member of the Programme Committee and Editorial Board of some of the main conferences and journals in these fields; member of the Steering Committee of EuroGP, EvoMUSART and Evostar; and executive board member of SPECIES.

He is the recipient of several scientific awards, including the prestigious EvoStar Award for outstanding Contribution to Evolutionary Computation in Europe, and the award for Excellence and Merit in Artificial Intelligence granted by the Portuguese Association for Artificial Intelligence.

Penousal Machado has been invited to perform keynote speeches in a wide set of domains, from evolutionary computation to visualization and art. His work was featured in the Leonardo journal, Wired magazine and presented in venues such as the National Museum of Contemporary Art (Portugal) and the "Talk to me" exhibition of the Museum of Modern Art, NY (MoMA).

Description of the Research Groups

CISUC performs research on the areas of computer science and information and communication technologies. The Centre has 150 integrated researchers, 72 with PhD, organised in 6 groups:

- Adaptive Computation (AC)
- Cognitive and Media Systems (CMS)
- Communications and Telematics (CT)
- Evolutionary and Complex Systems (ECOS)
- Information Systems (IS)
- Software and Systems Engineering (SSE)

To promote cohesion, gain critical mass, and foster inter-group synergies, the groups cluster into 3 thematic strands: Resilient Software and Internet Services (SSE, CT, IS), which focuses on internet architectures and technologies, cloud infrastructures and software services, and service oriented architectures; Intelligent Systems (AC, CMS, ECOS), which concerns the research and development of computational methodologies for search, modelling, optimisation, learning and visualisation; Human-Centric Computing (IS, CMS) encompasses computer-enabled, individual and social phenomena, leading to new emergent extensions of human capabilities and organisational models.

The work associated with these scholarships falls within the scope of an ongoing collaboration between the **CMS** and **ECOS** groups.

The goal of the **CMS** group is to provide context for specialized team research on Artificial Intelligence (AI), Information Visualization, Computational Creativity, Ambient Intelligence, and ICT for Education, stimulating theoretical and empirical study, the design and development of models and tools, and the use of research results in innovative applications with high social and scientific relevance.

ECOS is a research group of CISUC aiming at exploring the possible cross-fertilization between physical, biological and social systems directed towards the solution of complex problems in different domains. Our interests include: Evolutionary Computation, Machine Learning and Data Science.

Description of the Work

Evolutionary Multitask Learning

In nature, minds (and bodies) are the result of evolution and life-long learning. The natural transfer of this base idea to the computational field implies: the evolution of brain structures and hyper-parameters using Evolutionary Computation (EC); training the individuals of the population during their lifetime; valuing individuals that depict a better ability to learn, thus exploring the Baldwin effect, i.e. what is transmitted to the next populations is the ability to learn and not what was learnt.

The sub-field of Evolutionary Machine Learning (EML) that specialises on ANNs is known as NeuroEvolution. NeuroEvolution approaches are often grouped according to the aspects of the ANNs they focus on to optimise: (i) learning, either by evolving the learning parameters,

the learning rules, or by directly promoting the evolution of the weights and bias values; (ii) topology; or (iii) learning and topology.

The vast majority of the approaches address the optimisation of specific network structures, or the evolution towards specific problems. We intend to develop and use EC techniques that make generalization easy.

In particular, we are interested in using grammar-based methods. This way, the network structure and target problem can be defined in a human-readable fashion, by means of a context-free grammar. Consequently, to apply the approach to a new problem it is only necessary to define a new grammar, avoiding or minimising the need to change the code.

Following these ideas, we have developed DENSER — a novel layer-based NeuroEvolution approach that combines the principles of Genetic Algorithms with Dynamic SGE to automatically promote the discovery of the structure and learning hyper-parameters of deep networks.

The main difference between transfer and multi-task is on how the multiple tasks are learnt: in transfer we pass from one task to the next, but by the end of the second task we are often unable to provide an answer to the first problem, also known as catastrophic forgetting; in multi-task learning the various tasks are learnt simultaneously, and therefore by the end of evolution we must be able to correctly predict instances of the multiple problems. PathNet is an example of a multitask method. Building on the work being carried at our group, the main goal of this task is to propose an EC framework to evolve models that can be used in multiple domains, thus avoiding catastrophic forgetting.

Other Information

University of Coimbra

The University of Coimbra (UC) is a Portuguese public and autonomous higher education institution created in 1290. It embraces ten research and education units: Faculties of Law, Medicine, Arts and Humanities, Pharmacy, Economy, Sciences and Technology, Psychology and Education Sciences, Sport Sciences and Physical Education. Also the European Judicial University Court and the Institute of Nuclear Sciences Applied to Health. There are, also, units supporting cultural, training and education activities, such as the Common Library, the University Stadium, or the Botanical Garden. University's buildings are distributed among three campi, sums up to 124 buildings.
The University of Coimbra is part of an UNESCO World Heritage place "University of Coimbra, Alta and Sofia", since 2013; UC enrolls several UNESCO chairs.
Internationalization has been one of the University of Coimbra's main concerns with special effect in Education and Training.

Regarding Education, the University manages 36 undergraduate degrees, 123 master degrees and 72 doctorates. It is worth highlighting the collaboration within MIT and UT Austin, as well as the Research and Training activities undertaken by the Centers and Laboratories - over 39 units, submitted to 2018-evaluation by international panels; in 2018/2019, 222 PhD thesis where concluded.

On the subject of Transfer of Knowledge, UC deepens the innovation policy through INOV C, an Innovation Ecosystem that comprises more than 500 partners. Spin-offs such as Luzitin, LaserLeap, InEye, TreatU, Active Aerogels, Critical Software, Feedzai, demonstrate this innovation environment

The City of Coimbra

The City of Coimbra has its own very special charm, the result of a past full of important events and of the memories of the many thousands of Portuguese who, dispersed around the country or abroad, remember the carefree, easy-going, hopeful years spent here in their youth as students at the University. Prehistoric remains are scant but allow us to establish an early human presence on the site of present-day Coimbra.

From the Roman period we have the cryptoporticus. This is situated under the former Bishop's Palace, which now houses the National Museum Machado de Castro. With the fall of the Roman Empire came the arrival of new invaders, commonly known as barbarians: Vandals, Suevi, Alans and later Visigoths, who all left their mark on the city. In 711 the city was occupied by the Moors and remained Islamic for more than 300 years, despite brief interludes when Christian troops regained control. With the final Reconquest in 1064, by the army of Ferdinand the Great, Coimbra was ideally situated to be a point of contact between the Muslim south and the Christian north and became home to an important Mozarabic community.

As the country's first capital for 200 years during the reigns of the earliest monarchs, Coimbra's profile was raised by the founding of the University, which led to the formation of an urban nucleus full of noteworthy buildings. After 1537 there appeared numerous University colleges, and two areas – next to the Royal Palace in the upper town and in the Rua da Sofia (lower town) – were set aside for learning.

In the 18th century Coimbra maintained its academic vocation, which was strengthened by the Marquis of Pombal's reform of the University. The new buildings resulting from this reform changed the appearance and structure of the university campus, giving new importance to Natural and Experimental Science.

The 19th century was a period of considerable growth in population giving rise to new streets and residential areas, in particular the development of the estates belonging to the Sta. Cruz Monastery.

The 20th century saw many more great changes to the city with the building of the new university campus that obliged the residents of the upper town to be moved to new residential districts. In the 1990s the city expanded towards Vale das Flores and Boavista, where the University's second campus (Polo II) was built on the right bank of the River Mondego. Dedicated to Science and Technology, this features buildings by some of the

best-known contemporary architects. A third campus (Polo III) dedicated to the Life Sciences has been built near the University Hospitals in the Celas area.

Recently, the *University of Coimbra — Alta and Sofia* as been classified as a UNESCO world heritage site, recognizing irrefutable role as a centre of production and transmission of knowledge, within a geographical area that covers four continents – the ones corresponding to the ancient Portuguese Empire. The University of Coimbra — Alta and Sofia has used over this period, but mostly after its settlement in the city of Coimbra, the cultural, artistic and ideological influences of the former empire context inspired particularly by the pioneer charisma of the Portuguese Discoveries. While doing so, it received and disseminated knowledge throughout the fields of arts, sciences, law, architecture, town planning and landscape.

What to do in Coimbra?

The *University of Coimbra — Alta e Sofia*, is an extraordinary architectural set that, simultaneously, illustrates the several purposes of a university created in the Middle Ages, and the various significant periods of the Portuguese architecture and art, as well as of a national geographical and cultural space – the former Portuguese Empire.

Its history is closely connected with the ideological, pedagogical and cultural reformations, which hold a direct correlation to a material dimension. Through its set, the University represents a long cultural genesis, always present, active and architecturally and aesthetically verifiable in the several buildings that constitute it, and that are located in the World Heritage applicant areas – *Alta* and *Sofia*.

The Botanical Garden was an integral part of the Faculty of Natural Philosophy and was created during the Marquis of Pombal's reform of the University in 1773 and only completed in the 19th century.

The survival of some of the buildings of the former Benedictine College, such as the old chapel in the woods, endows the place with a romantic historical air.

In addition to the Botanical Garden's various works of architecture and sculpture, there is an extensive biological heritage, involving thousands of ancient plant species. Its exuberant vegetation reflects botanical studies and contacts with the four corners of the earth.

The University Palace (Paço Real) reveals the intimate connection of the University with royal patronage. It features a plethora of buildings and rooms that are worth visiting. We highlight the baroque library "Biblioteca Joanina", which was created as a study library and reserved to the university community, and is currently considered one of the most beautiful libraries in the world. Likewise visiting the "Sala dos Capelos" the place where all PhD examinations, including those of the members of the organising team, usually take place is certainly worthwhile.

The Chemistry Laboratory is the home of the Science Museum of the University, together with the Physics Museum, located across the street, they feature an important collection of experimental collection of instruments of the 18th and 19th centuries that is certainly worth a visit.

The construction of the Old Cathedral began in the 12th century. The Romanic church, built in yellow limestone, is located on a slope and is composed by three aisles, prominent transept and threefold headboard. The one floor cloister, located on the southern side of the church was built in the beginning of the 13th century.

Many other relevant buildings are available to this world heritage site, whose description can be found at http://worldheritage.uc.pt/.